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Energy policy and alternative energy in Malaysia: Issues and challenges for sustainable growth

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ABSTRACT

Energy is essential to the way we live. Whether it is in the form of oil, gasoline or electricity, a country's prosperity and welfare depends on having access to reliable and secure supplies of energy at affordable prices. However, it is also one of the benefits taken for granted by many people, knowing little about the impact of electricity on their lives. Having dependent mainly on oil and gas for half a century, Malaysia has started to realize the importance to adopt renewable energy in the energy mix and continuously reviewed its energy policy to ensure sustainable energy supply and security. This paper examines and discusses the intricacy of the existing and new energy policies, issues and challenges in Malaysia. The overall approach in addressing the energy issues and challenges will continue to focus on adequacy, quality, security and sustainability of both non-renewable and renewable energy supply in the country's development and the promotion and implementation of its energy efficiency programs. The recently launched National Green Technology Policy is also discussed.

Contents

1. Introduction

According to estimates done by the International Energy Agency, a 53% increase in global energy consumption is foreseen by 2030, with 70% of the growth in demand coming from developing countries. These growth trends exacerbate the challenge connected to limitations in energy supply, and the resulting competition for resources. Currently, with a total of 20,493 MW installed capacity, the energy reserve margin of Peninsular Malaysia stands at 47%. With an average of 4% annual growth, it is estimated that the maximum demand of electricity will be at 23,099 MW in 2020, which is nearly twice the current demand [1]. At present, every 1% growth in gross domestic product (GDP) is accompanied by a growth in energy demand (and

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associated greenhouse gas emissions) of 1.2–1.5%. With increasing industrialization, electricity consumption has increased from 19,932 GWh in 1990 to 87,164 GWh in 2007, an increase of 337%. In fact, the period from 1990 to 2000 marked the period of rapid economic growth where demand for electricity recorded double digit growth [2].

The excessive exploitation of the natural resources make possible by the advancement of technologies has resulted in unwanted by-products such as waste and pollution. Fossil fuels consume and pollute water, endanger flora and fauna, generate toxic wastes and cause global warming. Consequently, we are now facing bigger challenges in finding solutions to overcome the problem of depleting natural resources, climate change, energy supply and food security. Meeting the increasing demand for energy is indeed a subject that continually plagues the government. This is further compounded by the concerns on the effect on the environment as a result of burning fossil fuels and the persistently high energy costs for the past few years.

The Malaysia Federal Government and the Non-Financial Public Enterprises (NFPEs) have invested a substantial amount of allocation to continue providing an adequate, reliable and reasonably priced supply of electricity to the people. For example, a total of RM27.9 billion (US$7.75 billion) was spent in the electricity supply sector under the 8th Malaysia Plan to undertake electricity sector programs in generation, transmission, distribution as well as rural electrification. The amount is expected to increase to RM30 billion (US$8.33 billion) under the 9th Malaysia Plan. With these investments and coupled with strong policy measures, the electricity coverage in Malaysia is expected to increase to 95.1% in 2010 from 89.5% in 2000, with the rural electrification rate in Peninsular Malaysia currently at 99% [2]. Figs. 1 and 2 show the total energy demand and the energy mix trend in Malaysia, respectively.

The crucial challenge facing the power sector in Malaysia all this while is the issue of sustainability that is to ensure the security and reliability of energy supply and the diversification of the various energy resources. The question of security and reliability of supply is critical, to ensure smooth implementation of development projects to spur economic growth in Malaysia while diversification of energy resources is critical to ensure that the country is not dependent only on a single source of energy [3].

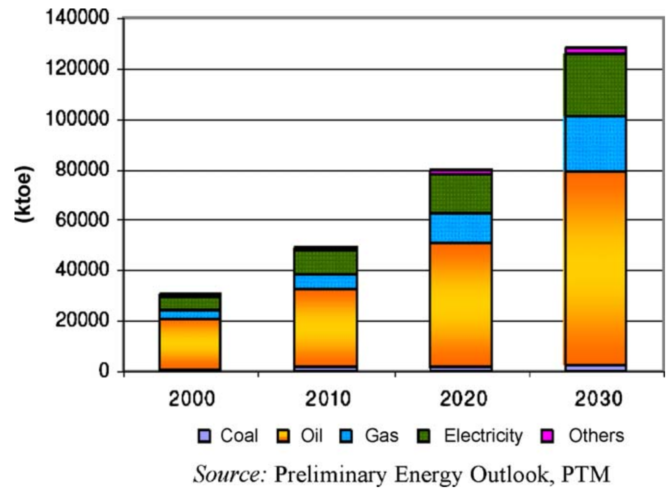

Fig. 1. Total energy demand (ktoe). *Source*: Preliminary Energy Outlook, PTM.

Today, the world is more circumspect. Green technology application is seen as one of the sensible solutions which are being adopted by many countries around the world to address the issues of energy and environment simultaneously. Green technology is a technology that allows us to progress more rapidly but at the same time minimizes the negative impact to the environment. However, the world needs to find more efficient and effective ways to adopt green technology against other technologies which have been widely used and though cheaper, not necessarily benevolent.

Investment in sustainable energy sources in 2008 has defied the global recession. Last year marked the first time that investment in new power generation capacity sourced from renewable energy (RE) technologies, estimated at US$140 billion including large-scale hydro, was more than investment in fossil-fuelled technologies, approximately US$110 billion. In Malaysia, there seems to be renewed impetus in promoting the growth of an indigenous "green economy". Not only does the country face the growing threat of climate change and pollution, but the government also have to find new sources of growth and move up the value chain. Therefore, the aim of this paper is to describe the numerous energy policies which

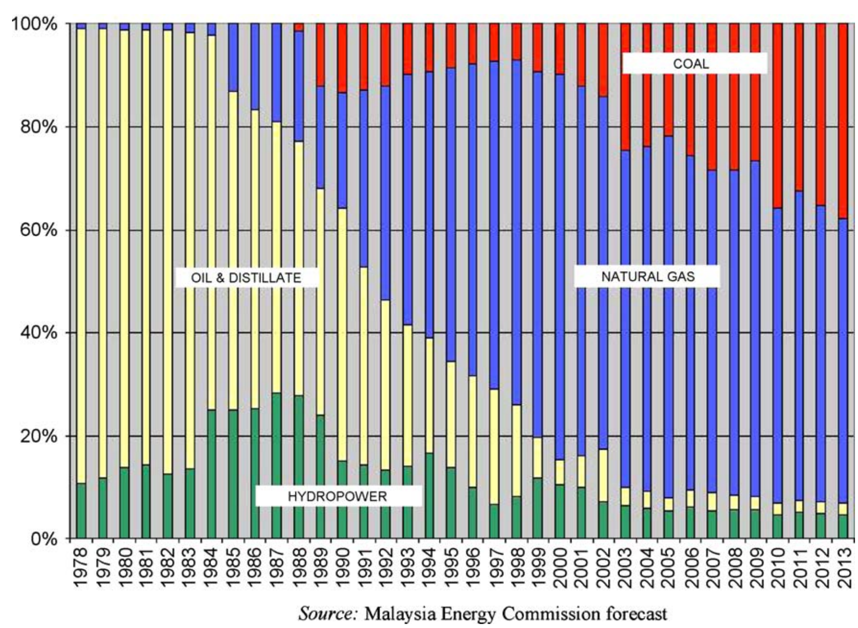

Fig. 2. Energy mix trend in Malaysia. *Source*: Malaysia Energy Commission forecast.

have been adopted in Malaysia thus far, including the newly launched National Green Technology Policy, to ensure long-term sustainability, reliability and security of energy supply for continuous development growth. This paper will also update and discuss on both the non-renewable and renewable energy (RE) sources in the existing Five-Fuel Diversification Strategy energy mix. The most recent various alternative energies available and the various energy efficiency programs in Malaysia will also be presented. Lastly, we will cover the challenges faced in the green and RE implementation.

2. Energy policies and outlook in Malaysia

For the past 60 years, Malaysia government has formulated quite a number of energy-related policies to ensure sustainability and security in energy supply, with the very first policy dated back to 1949 when the Central Electricity Board (CED) was first formed, before it was changed to National Electricity Board (NEB) in 1965. But over the last three decades, pragmatic energy policies have facilitated a more environment-friendly energy development path. The first policy that really impacted the industry was the Petroleum Development Act 1974, vested on PETRONAS, the state-owned oil and gas company, the exclusive rights to explore, develop and produce petroleum resources in Malaysia, followed by the National Petroleum policy 1975 to regulate downstream oil and gas industry via the Petroleum Regulations 1974. The more significant policy, the National Energy Policy was actually introduced in 1979 with three primary objectives; supply, utilization and environmental. The first objective is to ensure the provision of adequate, secure, and cost-effective energy supplies through developing indigenous energy resources both non-renewable and renewable energy resources using the least cost options and diversification of supply sources both from within and outside the country. The second objective is to promote the efficient utilization of energy and to discourage wasteful and non-productive patterns of energy consumption, and the last objective is aimed to minimize the negative impacts of energy through efficient energy utilization. After that, the National Depletion Policy 1980 and a year later, the Four-Fuel Diversification Strategy 1981 were implemented, with the former to prolong lifespan of the country's oil reserves for future security and stability of oil supply and the latter to pursue balanced utilization of oil, gas, hydro and coal.

The fuel diversification policy in Malaysia is reviewed from time to time to ensure that the country is not over-dependent one main energy source, especially after the two occurrences of international oil crisis in 1973 and 1979. The policy was further revised in 1999 with the announcement of the Five-Fuel Diversification Strategy. Renewable energy (RE) was made the fifth fuel in the energy supply mix with the target to contribute 5% of the country's electricity demand by year 2005. In order to meet this goal, the Small Renewable Energy Program (SREP) was launched in May 2001 under the initiative of the Special Committee on Renewable Energy (SCORE) aimed to support the government's strategy in intensifying the development and utilization of RE as the fifth fuel resource in power generation, which is also stipulated in the objectives of the Third Outline Perspective Plan (OPP) for 2001–2010 and the 8th Malaysia Plan (2001–2005). The primary focus of SREP is to facilitate the expeditious implementation of grid-connected RE resource-based small power plants. In the 9th Malaysian Plan (2006–2010), the emphasis on energy efficiency is intensified to address the nation's energy challenge in line with the sustainable development agenda.

Before the Five-Fuel Diversification Strategy in 1999, oil made up a large portion of the country's energy mix for the past few decades. After faced with the possibility of prolonged energy crisis back in the 1970s, other options of energy resources such as natural gas, coal and hydro became viable, as natural gas and hydro were largely untapped then, and coal was considered a plentiful and reliable worldwide resource with low and stable price. Direct consequence from this strategy saw the contribution of oil in the energy mix dropped drastically from a high 87.9% in 1980 to 4.2% in 2000 as shown in Table 1, and projected to drop below 1% by 2010 [4]. On the other hand, natural gas and coal have become the two main contributors in the energy mix, followed by hydro. Oil is no longer seen as a feasible source to generate electricity due to its fast depleting supply and nowadays, it is mostly used as back-up supply for emergency.

Table 1
Energy mix in Malaysia.

Source	1980 (%)	1990 (%)	2000 (%)	2005 (%)	2010 (%)
Oil/diesel	87.9	71.4	4.2	2.2	0.2
Natural gas	7.5	15.7	77.0	70.2	55.9
Hydro	4.1	5.3	10.0	5.5	5.6
Coal	0.5	7.6	8.8	21.8	36.5
Biomass	–	–	–	0.3	1.8

Source: BioGen (2003); 9th Malaysia Plan (2006–2010), Table 19-5.

However, the burning of fossil fuels (coal and oil) and natural gas may result in one day these resources will be totally exhausted and will significantly contribute to the emission of greenhouse gases (GHG) from their combustions, raising the climate change issue. Thus, in addition to fifth policy, the government has ratified Kyoto Protocol in September 2002. As Malaysia is non-Annex 1 country, Malaysia can utilize the Clean Development Mechanism (CDM) to reduce domestic CO_2 emissions as well as transfer advanced technologies from developed countries.

As a rapid developing nation, the energy consumption in Malaysia will no doubt keep increasing, raising a lot of energy challenges. The 8th Malaysia Plan (2001–2005) had targeted to generate 5% of the country's electricity from RE by 2005, but only 0.3% was achieved. This was further emphasized in the 9th Malaysia Plan where efforts in the utilization of RE resources and efficient use of energy were further promoted. The establishment of the Ministry of Energy, Green Technology and Water to replace the Ministry of Energy, Communications and Multimedia earlier this year reflects Malaysia's seriousness in driving the message that 'clean and green' is the way forward towards creating an economy that is based on sustainable solutions. The launch of the new National Green Technology Policy in April 2009 by the current Prime Minister, Datuk Seri Najib Tun Razak, that follows shall provide guidance and create new opportunities for businesses and industries to bring a positive impact to the economic growth. The National Green Technology Policy is built on four pillars – (1) seek to attain energy independence and promote efficient utilization; (2) conserve and minimize the impact on the environment; (3) enhance the national economic development through the use of technology; and (4) improve the quality of life for all. It will also be the basis for all Malaysians to enjoy an improved quality of life, in line with the national policies, including the National Outline Perspective Plan, where the growth objectives for the nation will continue to be balanced with environmental consideration [5]. While fossil fuels are expected to remain the dominant source of energy for decades to come, RE such as wind, solar, biomass, biofuel and geothermal heat are expected to double between now to year 2030, although their share in the energy mix is most likely still be around 5.9% of the total energy demand by 2030 [6].

3. Energy mix

Malaysia has adopted the Five-fuel Diversification Strategy energy mix since 1999, whereby the five main sources are oil, natural gas, coal, hydro and RE.

3.1. Oil

The contribution of oil in Malaysia energy mix was once up to 87.9% before the Four-Fuel Diversification Strategy was implemented in 1981. After the international oil crisis in 1973 and 1979, the government had called for the diversification of energy resources to prevent over-dependency on oil. Malaysia has proven oil reserves of 5.46 billion barrels as of January 2008 [7]. The majority of the country's reserves are located off the east coast of Peninsular Malaysia and tend to be of high quality. Several new oil production projects have come online during the last few years, although Malaysia's oil output declined somewhat in 2006. Average production for 2006 stood at 798,000 barrels/day (bbl/d), down 7% from 2005 levels. In 2006, Malaysia consumed an estimated 515,000 bbl/d of oil, with net exports of about 283,000 bbl/d. According to *Oil and Gas Journal*, Malaysia had about 545,000 bbl/d of refining capacity at six facilities as of January 2007.

Malaysia's state-owned national oil company, Petroleam Nasional Berhad (PETRONAS), dominates upstream and downstream activities in the country's oil sector. PETRONAS operates three refineries (259,000 bbl/d total capacity), while Shell operates two plants (200,000 bbl/d), and ExxonMobil one (86,000 bbl/d). Malaysia has invested heavily in refining activities during the last two decades, and is now able to meet the country's demand for petroleum products domestically, after relying on the refining industry in Singapore for many years.

Despite growth in exploration activities and several new projects that are set to come on-stream in the next several years, Malaysia's proven oil reserves have declined in recent years and the oil production fell to 693,000 bbl/d in 2008, a 13% decrease from 2006 level [8]. Provided that the production rate is consistent at around 700,000 bbl/d, Malaysia's oil reserves will be exhausted in around 20 years.

3.2. Natural gas

In Malaysia, this natural source which can be found in abundant has become the main energy contributor since early 2000s. Since its discovery in 1983, its contribution in the energy mix has grown significantly since, replacing oil as the main source. As in Jan 2008, Malaysia held 88 trillion cubic feet (Tcf) of proven the natural gas reserves [7]. While much of the oil reserves are found off Peninsular Malaysia, most of the natural gas production comes from East Malaysia, especially offshore Sarawak. Malaysia has three LNG processing plants, all located in a massive complex at Bintulu (East Malaysia) and supplied by the offshore natural gas fields at Sarawak. The Bintulu facility is the largest LNG complex in the world, with a total liquefaction capacity of 22.7 million metric tons (MMt), or equivalent to 1.1 Tcf per year. Natural gas reserves in Malaysia is the second largest in South East Asia after Indonesia and its production has risen steadily in recent years, reaching 2.2 Tcf in 2004, up 47% since year 2000. Domestic natural gas consumption has also increased substantially, with 2004 consumption at about 1.2 Tcf, which is 61% higher than year 2000 level. Malaysia is a significant net exporter of natural gas, primarily in the form of liquefied natural gas (LNG). In 2005, Malaysia exported 21.2 MMt of LNG, which accounted for 15% of the total world LNG export.

Malaysia has one of the most extensive natural gas pipeline networks in Asia, owing to the multi-phased Peninsular Gas Utilization (PGU) project completed in 1998. The goal of the PGU is to expand natural gas transmission infrastructure on Peninsular Malaysia. The PGU system spans more than 880 miles and has the capacity to transport 2 billion cubic feet/day (Bcf/d) of natural gas. Not only has the PGU initiative helped boost domestic natural gas consumption, it has also expanded regional natural gas trade. Malaysia already trades small amounts of piped natural gas with Singapore and Indonesia, and PETRONAS reported that in 2006 construction was completed on the Trans-Thailand–Malaysia Gas Pipeline System, which allows Malaysia to pipe natural gas from the Malaysia-Thailand JDA to its domestic pipeline system. This linkage marks a significant step toward the realization of the proposed "Trans-ASEAN Gas Pipeline" (TAGP) system, which envisions the establishment of a transnational pipeline network linking the major natural gas producers and consumers in South East Asia. On account of Malaysia's extensive natural gas infrastructure and its location, the country is a natural candidate to serve as a hub in the proposed TAGP project [9].

Based on the ratio between the reserves and production rate (assume that it has remained about the same up to now), it indicates that the natural gas could still contribute to the energy mix as the main source of energy for the next 36 years compared to oil which is only around 20 years. At the moment, almost 80% of the energy mix in Malaysia is contributed by natural gas. As in the oil sector, PETRONAS dominates the natural gas sector as well.

3.3. Coal

Malaysia has coal resources located in the states of Selangor, Perak, Perlis, Sarawak and Sabah. Current production of coal comes primarily from six mines in Sarawak. The DMG has estimated the country's coal resources at some 1724 million tons of which 274 million tons are measured, 347 million tons indicated and the balance of 1102 million tons as inferred. Some 80% of the resources are located in Sarawak, 19% in Sabah and one per cent in Peninsular Malaysia. The largest reserves of coal are located in Merit Pila, Sarawak and in Maliau and Malibau, Sabah. Output in 2007 increased to 1,063,078 tons from 901,801 tons in 2006. Malaysia's demand for coal has been on the rise, with 15 million tons in 2008 and is expected to rise to 19 million tons by 2010. Most of the country's requirements are met by imports from Indonesia, Australia and China. They are consumed mainly by the power generation and cement plants, and to a lesser extent by the iron and steel plants. The country aims to boost coal's share of the overall energy mix from the present 18–30% by 2010. The total energy consumption in Malaysia from coal is 30% or 14,200 MW in 2008 and it is expected to increase to 42% or 17,600 MW in 2013 [10]. Most of the coal is imported but efforts are continuing to enhance the security of supply by exploring the potential for development of local sources, particularly in Sarawak, as well as securing long-term supplies from abroad.

Currently, there are four coal fired plants to which Tenaga Nasional Berhad (TNB), Malaysia's state-owned power company, arrange coal supplies to. TNB owns two of the plants – Kapar (1600 MW) and Janamanjung (2100 MW) plants. Two others are independent power producers (IPPs), namely Tanjong Bin (2100 MW) and Jimah (1400 MW).

3.4. Hydro

In the light of the constraints in fossil fuel supply as well as the ensuing high prices caused by resource nationalism around the world, hydro power is expected to play a more prominent role in our generation mix. Its share in the generation mix is expected to increase from 5% in 2008 to 35% in 2030 for Peninsular Malaysia. The share of gas in the generation mix is projected to decline from the current 60% to about 30% for the same period if the consumption level maintains at 1350 mmscfd. In view of this the government intends to ensure that TNB maintains the reserve margin at around 20% in Peninsular Malaysia. The state government of Sarawak has recently announced plans to develop several

large hydroelectric projects under the Sarawak Corridor of Renewable Energy. The development spanning over a period of 22 years has the potential to generate 28,000 MW of electricity once fully developed. The Bakun dam in Sarawak, one of the largest dams in South-East Asia, is expected to finally complete by 2010 (this project was halted twice in 1997 and 2001 due to the Asian Financial crisis) with a capacity of 2400 MW. The Bakun hydroelectric dam project involves the construction of a 205 m high rock-filled concrete dam to create a reservoir that spans a massive 695 km^2. The Bakun project is expected to cost some RM7 billion (US$2 billion) while TNB together with Sarawak Energy Ltd. are to form a consortium to build a 1650 km transmission system that will cost another RM9 billion (US$2.57 billion) of which 650 km will be the undersea submarine cable [11]. Plans are underway to export about 5000 MW of power in the medium term to Peninsular Malaysia via 500 kV high-voltage direct current overhead (HVDC) and undersea cables by 2020 and an additional 5000 MW by 2030. By 2030, hydroelectricity is expected to account for about 30–35% of the generation mix. Amongst the projects which are already identified to be developed are the Murum dam (940 MW), Baleh dam (950 MW) and Pelagus dam (770 MW) in the upper reaches of the Rejang river in Sarawak. The Sarawak State Government has awarded the construction of the Murum dam to a successful bidder with an expected completion date by 2013. Whereas, for the Baleh and Pelagus dams feasibility studies are being conducted [2].

3.5. Renewable energy (RE)

Rapid depletion of fossil fuel reserves as well as climate change has driven the world towards RE sources which are abundant, untapped and environmentally friendly. In particular biomass fuels hold great promise as a component of Clean Development Mechanism (CDM) strategies in the Kyoto Protocol to reduce GHG emissions to acceptable levels. The Biomass Energy Plant Lumut is the first Malaysian project to be registered at the UNFCCC as a CDM project. The first large scale CDM project to be registered from Malaysia is this project where biomass is co-fired with coal in cement kilns in two cement works in Kanthan and Rawang. The Jendarata steam and power plant and Jenderata palm oil mill have the expected combined emission reduction of carbon dioxide of more than 30,000 tons annually.

Aforementioned, RE was added as the fifth source of energy when the Five-Fuel Diversification Policy replaced the four-fuel policy back in 1999 with the target to contribute 5% of the total energy mix by 2010 in the 8th Malaysia Plan (2001–2005). The development pace of RE in Malaysia is rather slow and still at its infancy, with its current contribution at around 1% only of the total energy mix, even though the fifth fuel policy had been announced a decade ago. Presently, RE in Malaysia is still being generated on a small-scale basis only although Malaysia is blessed with abundant of resources available on renewable basis, with mostly from mill wastes such as such as palm oil, rice, sugar cane, timber/sawmill, paper recycling, municipal waste, biogas, to name a few. Nevertheless, credit should be given for the continuous concerted efforts undertaken by the government all these years to promote and develop the benefits and utilization of RE resources.

In tandem with the government's efforts, the Small Renewable Energy Power (SREP) Program was launched in May 2001 and initially covered biomass, biogas, landfill waste and mini-hydro. Later in 2003, solar PV and wind were incorporated into SREP as well. Under the SREP Program, the utilization of all types of RE sources is allowed. Small power generation plants utilizing RE sources can apply to sell electricity to the utility through the country's distribution grid system. Maximum capacity of small RE plant designed for sale of power to the grid must not exceed 10 MW. A Special Committee on Renewable Energy (SCORE) has been set up under the then Ministry of Energy, Communications and Multimedia to coordinate the program and a secretariat functioning as a One-Stop Centre at the Energy Commission (EC) facilitates industry participation in the program. Latest report from Malaysia Energy Centre (PTM – Pusat Tenaga Malaysia) shows 60 projects have been approved as in 2005, using various types of renewable energies (see Table 2), with the most coming from biomass using palm oil wastes and mini-hydro. All these projects, with each given a 21-year operating license to generate up to a maximum of 10 MW, manage to generate a total of 375 MW energy with 325 MW connected back to the national distribution grid. Among all the sources of RE, biomass appears to be the most promising, especially from empty fruit bunches since Malaysia is one of the world's top producers of oil palm. PTM estimates the country has the capacity to produce up to 2000 MW using biomass and biogas alone.

Biomass Power Generation and Demonstration (BioGen) Project was introduced in October 2002 with the main objective to reduce the growth rate of GHG emissions from fossil fuel by utilizing excess oil palm biomass residues and further promote and demonstrate biomass and biogas grid-connected power generation projects. The project is jointly funded by Malaysia Government, United Nations Development Program, Global Environment Facility and various Malaysian private sectors. BioGen also facilitates development of the grid-connected biomass-fuelled small power systems, disseminates awareness information in palm oil industry, provides building and technical assistance in policy formulation, and financial facility assistance through favourable bank loans and tax exemption among others. To date, some of BioGen significant projects include the first 14 MW (export 10 MW) power plant in Tawau, Sabah which uses oil palm residues (empty fruit bunch, fibre and shell) that successfully mitigate 40,000–50,000 tons of CO_2 in 2004 and more recently, a 13 MW (export 10 MW) and 500 kW (FELDA Serting) power plants are grid-connected and commissioned in July 2009 and a total of 447 MW off-grid electricity has been produced by private palm oil millers.

Table 2
Status of SREP projects approved by SCORE as at 2005.

Type	Energy resource	Approved application	Generation capacity (MW)	Grid connected capacity (MW)
Biomass	Empty fruit bunches	25	220.5	174.8
	Wood residues	1	6.6	6.6
	Rice husk	2	12.0	12.0
	Municipal solid waste	1	5.0	5.0
	Mix fuels	3	19.2	19.2
Landfill gas		5	10.2	10.0
Mini-hydro		26	101.9	97.4
Wind and solar		–	–	–
Total		63	375.4	325.0

Source: Energy Sector Incentive Workshop 23–24 December 2005.

Table 3
Renewable energy potential in Malaysia.

Renewable Energy	Potential (MW)
Hydropower	22,000
Mini-hydro	500
Biomass/biogas (oil palm mill waste)	1,300
Municipal solid waste	400
Solar PV	6,500
Wind	Low wind speed

Sources: Malaysia Energy Centre's National Energy Balance.

Apart from biomass, in 2005, the government introduced the use of biodiesel for the transport sector as a step towards sustainable energy development through diversification of energy sources. Back in the 1980s, the then Palm Oil Research Institute of Malaysia (PORIM) developed biodiesel using transesterification technology that was used 100% on special engines from Germany. In spite of that, biodiesel received lacklustre interest from transportation and automobile industry due to unclear policy and directive from the government and also hindered by the high price of the palm oil and low price of oil back then. The increasing oil prices and falling palm oil prices in the recent years have somehow revived the interest, with legislation to require oil companies to sell biodiesel at their petrol stations. The biodiesel raw material is refined, bleached and deodorized (RBD) palm oil and its composition is 5% processed palm oil blended with 95% petroleum diesel for diesel engine vehicles and industrial and power generation [12]. In 2006, Malaysia's biofuel production stood at 400,000 tons and increased to 1 million tons a year later, which is mainly for export market. The increase in biofuel production was achieved through yield increase and production efficiency without increasing the hectarage of plantation.

Table 3 summarized the rough estimation of the RE potential in Malaysia in the long run. Hydropower and solar PV are without the RE with highest potential due to Malaysia's geographical terrain with many large rivers suitable for dam projects and its tropical climate with plenty of sunlight.

4. Alternative energy

Apart from the main five energy sources stated in the Five-Fuel Diversification Strategy, the government has always been on the lookout for other possible sources of alternative energy such as solar, wind, hydrogen fuel cells, landfill gas and municipal solid waste (MSW) incineration and more recently, nuclear.

4.1. Solar

Although solar power has been identified and incorporated into SREP as one of the REs in 2003, it is introduced here separately from the RE in the section 3.5 sub-category because most of the solar power used in Malaysia is domestic level only (mostly for solar thermal), and large scale commercial use is not significant yet. Solar power in Malaysia or also known as photovoltaic (PV) system is estimated to be four times the world fossil fuel resources [13], but the truth is that the potential of solar power is practically limitless. Presently, solar energy applications mostly oriented towards domestic hot water systems, water pumping, drying of agricultural produce. The tropical climatic conditions in Malaysia are favourable for the development of solar energy due to abundant sunshine with the average daily solar insulation of 5.5 kWm^2, equivalent to 15 MJ/m^2. PV-generated electricity, whether standalone or grid connected, is electricity generated at point of use. So, 1 MW of PV-generated electricity is equivalent in fuel saving to about 4 MW of conventional electricity once generation and transmission losses of the conventional system are factored in. It may be quite feasible to set a target of about 10 MW of grid connected photovoltaic system for Malaysia [14].

In 2005, the 5-year Malaysian Building Integrated Photovoltaic Technology Application Project (MBIPV) was launched. This project is jointly funded by the Government of Malaysia, the Global Environment Facility (GEF), and the private sector. It is intended to encourage the long term cost reduction of non-emitting GHG technologies by the integration of energy generating photovoltaic technology in building designs and envelopes. Over the lifetime of the project, the energy generated is expected to be able to avoid 65,100 tons of CO_2 emissions from the country's power sector [15]. The project has several demonstration PV projects in various sectors including residential houses and commercial buildings. The most significant recent project is the Green Energy Office (GEO) building, an administration-cum-research office for PTM. It is constructed following the success of the Low Energy Office (LEO) building which currently housed the Ministry of Energy, Green Technology and Water (KeTTHA) in Putrajaya. The LEO building is the first Malaysia's government building to be built with integrated energy efficient design and was designed as a showcase building to demonstrate energy efficient and cost effective features so that other public and private sector buildings can replicate such measures. The GEO building, on the other hand, is a pilot project, a demonstrator building which marked another milestone towards greater promotion and adoption of sustainable building concept. PTM-GEO is the only such building in Malaysia that integrates the energy efficiency (EE) and RE in one working building. The building integrated photovoltaics (BIPV) panels are all integrated into the building design to provide electricity for the building uses and are connected to the national electricity (TNB) grid by feeding electricity into the network and shaving the peak power demand of the grid during the peak daylight hours. The system provides almost 50% of everyday electrical needs. In daytime, the system will feed any surplus of energy back to the TNB grid. At night, the electrical energy is imported back from the grid to be used for the cooling system. Other green technology features of the building which are not in the scope of this discussion can be found in [16].

Another national MBIPV program that is worth mentioned is the SURIA-1000 program initiated in 2007, targeting the residential and commercial sector to establish the new BIPV market and provide direct opportunities to the public and industry in RE initiatives. Every year since 2007, limited number of grid-connected solar PV systems will be offered to the public on a bidding (auction) concept, through local mass media and administered by a project team, with minimum BIPV capacity for bidding is 3 kWp per application. Successful bidders would then install the PV system supplied by the participated PV service providers as BIPV at their premises. The costs of the PV systems are borne by the successful bidders at the bidding price and supplemented by the project. This program is co-financed by the public (owners of the system), Malaysia's Energy Commission and the PV industry. Today, the cost of a 5 kWp BIPV turn-key roof-top system in Malaysia is about RM27,000/kWp. Thus, a 5 kWp BIPV system costs RM135,000 (US$37,500). The system will produce approximately 6000 kWh of energy per annum [17]. To date, there are only a mere 0.4 MW of cumulative grid-connected PV installations and PV system unit cost has dropped by 16% in average since introduced.

4.2. Wind

Wind power is the conversion of wind energy into more useful forms, usually electricity using wind turbines. In 2005, worldwide capacity of wind-powered generators was 58,982 MW, their production making up less than 1% of worldwide electricity use.

Although still a relatively minor source of electricity for most countries, it accounts for 23% of electricity use in Denmark, 4.3% in Germany and around 8% in Spain. Globally, wind power generation more than quadrupled between 1999 and 2005.

In Malaysia, wind energy conversion is a serious consideration. The potential for wind energy generation in Malaysia depends on the availability of the wind resource that varies with location. Understanding the site-specific nature of wind is a crucial step in planning a wind energy project. Not much data are available on wind energy potential of Malaysia can be found. One dated back in the early 1980s was conducted the Solar Energy Research Group from Universiti Kebangsaan Malaysia (UKM). Wind data were collected from ten stations distributed all over Malaysia (six in Peninsular and four in east Malaysia, Sabah and Sarawak) for a 10-year period (1982–1991), with all the stations located either at airport, near open sea, flat area or meteorology department. The station located at Mersing (seaside) has the greatest potential with a mean power density of 85.61 W/m^2 at 10 m above sea level [18].

A more recent research in 2005, a 150 kW wind turbine in Terumbu Layang Layang was demonstrated with some success by a team from UKM. However, the availability of wind resource varies with location. It is necessary to first carry out a general assessment of the wind energy potential nationwide. This can then be followed with detailed assessment in promising locations. Understanding the wind resource is a crucial step in planning a wind energy project. Wind energy is considered a green power technology because it has only minor impacts on the environment. Wind energy plants produce no air pollutants or GHG and have great potential in tourist resort islands. However, any means of energy production impacts the environment in one way or another, and wind energy is no different [19].

4.3. Landfill gas and municipal solid waste (MSW)

Municipal Solid Waste (MSW) in Malaysia involves the disposal of approximately 98% of the total waste to landfills. Current disposal method of landfilling needs improvements to prolong the landfill life and to minimize the problem of land scarcity. Rapid developments and industrialization in Malaysia necessitate a better and more efficient waste management strategy. The mushrooming of urban areas and rural–urban migration has increased the per capita income due to changes in the consumption patterns that led to increased waste generation. The local authorities and waste management consortia have to handle approximately 17,000 tons of MSW everyday throughout the country [20]. The largest sources are household waste followed by industrial and commercial waste (Table 4). The MSW consisted of putrescible waste, paper, plastic, wood, metal, glass, textiles, grass and others. MSW contains significant portions of organic materials that produce gaseous products, an energy source known as biogas which is naturally produced from anaerobic degradation at landfills. The main content of the landfill gas (LFG) is methane, which can be used for power generation, transport and as cooking gas. Harvesting energy from landfills is befitting as there are more than 261 landfill sites in Malaysia and 150 sites are still operating, contributing to the immense potential of LFG formation. If the methane is left untapped, it becomes a major greenhouse contributor as methane is 23 times more hazardous than carbon dioxide in terms of its global warming effects [21]. Currently, the Landfill Gas (LFG) Power Generation at Air Hitam Sanitary Landfill, Puchong is the first grid connected RE project in the country. This project is owned by a subsidiary and its construction was completed in November 2003 and commissioned in April 2004. Generally, the project site is located at landfill area itself, where the total gross area of landfill is about 58 hectares and the waste deposited close to 4 million tons. This landfill area receives 3000 tons of garbage/day from major parts of the Klang Valley.

Table 4
Composition of solid MSW in Malaysia.

Sector	Weight (%)
Domestic	49
Industrial	24
Commercial/institutional	16
Construction	9
Municipal	2

Source: Malaysia Energy Centre 2008.

The 2.096 MW power plant has two gas engines rated at the capacity of 1048 kW and the generator comprises of a set of gas extraction system which is directly connected to the pipe from the gas field or well. The system functions as the fuel pre-treatment system of the biogas such as filtration, heating and cooling of the gas. The interconnection point of TNB substation with the gas power generator is located 30 m from the site, with 2 MW being exported to the national grid. Each well can produce biogas for a period of 20 years and the gas composition is more than 55% methane gas with an 80% maximum moisture level at a production rate of 40 m^3/h.

Besides power generation, this project also reduces odour level at surrounding area and mitigates emission of GHG [22]. The energy potential from an incineration plant operating based on 1500 tons of MSW/day with an average calorific value of 2200 kcal/kg is assessed to be at 640 kW/day [23].

Another popular method of MSW disposal in Malaysia is through open incineration and it is increasingly becoming a problem due to pollutant emissions like heavy metals and mercury, and other hazardous compounds such as dioxin, hydrochloric acid (HCl), nitrogen dioxide (NOx) and sulfur dioxide (SOx) being released to the atmosphere from clinical waste incineration process. Open incineration is seen as the easiest way to handle waste by many due to shortage of land for landfills and its rising costs. In the early 2000s, a US$435 million biggest incinerator project in Asia was proposed to be built in the country, to be located at Broga, Selangor. But the 1500-ton behemoth project had since been scrapped due to the large capital expenditure and costly maintenance involved, on top of mounting protests from the public and environmentalists because the proposed site was located near a university and surrounded by vegetable farms, palm oil and fruit plantations and near a water catchment area. At present, incinerators in Malaysia are run by private entities in small scale and mainly used for medical and hazardous wastes only. The government has not totally dispose the plan of building more incinerators in the future as solid waste management is getting more serious by days, with the country's capital, Kuala Lumpur alone discards some 3000 tons of solid waste every day. Consequently, there are renewed interest and ongoing studies on thermal treatment for solid waste management through gasification and pyrolysis, which look quite promising [24].

Only about 5–15% of waste in Malaysia is recycled, compared to much higher levels in many developed nations. According to the Malaysian Newsprint Industries, a private joint venture newsprint supplier, Malaysian publishers use about 250,000 tons of newsprint a year, of which only 100,000 tons is recovered. This is equivalent to disposing 2.55 million trees into the landfills. The main factor that might influence the composition and amount of MSW produced in any location is the extent of reduction, reuse and recycling programs being implemented, and there have been much disputes that the government's recycling campaign and its collection points, with large bins in three colours for the various types of waste, have been a failure. Where they existed, many of these bins are simply inaccessible or full of un-segregated rubbish. And most households did not have easy access to such recycling

Table 5
Projected amount of MSW generated by 2020.

Year	Population	Estimated amount of waste (tons/year)
1991	17,567,000	4,488,369
1994	18,917,739	5,048,804
2015	31,773,889	7,772,402
2020	35,949,239	9,092,611

Source: Malaysia Energy Centre 2008.

collection points. With the ever increasing population, it is projected that more than 9 million tons of waste will be produced a year by 2020 (Table 5). Composting can actually be incorporated in all the landfills in the country together with an integrated system of recycling. The integrated system would allow optimization of waste reduction and reuse programs, which is actually a realistic possibility to improve the MSW management in the country.

4.4. Hydrogen fuel cells

Being the most abundant element on earth, hydrogen (H_2) has been identified as one of the most viable and long term renewable alternatives to fossil fuel after solar. Other renewable such as biomass is currently seen not sufficient enough to replace fossil fuels. And fuel cell has been singled out as the most promising energy conversion device for hydrogen especially in transportation. The fuel cell is an electrochemical cell, which produces electricity directly from hydrogen and air (oxygen), without the production of GHG. In principle, although a fuel cell operates like a normal battery, it does not run out nor requires charging as long as fuel is supplied to it.

Unfortunately, hydrogen does not exist naturally and thus the extraction and production methods of hydrogen are very expensive. The most common form of extraction is steam reforming where water is heated to high temperature (roughly 1000 °C) using methane (CH_4), which reacts with the hydrogen (cultivated for use) and carbon monoxide (emitted as GHG). Another alternative version of extraction which is more expensive but also the cleanest is through breaking water molecules into hydrogen and oxygen using electrolysis. The main drawback is that it takes more energy to create the hydrogen than what is actually produced, making it not feasible. At the moment, research and development is being carried out to harness hydrogen to be used in fuel cells for transportation purposes. Hydrogen and fuel cells are identified as priority research by the Ministry of Science, Technology and Innovation (MOSTI) after solar, with RM7 million (US$2 million) funded on hydrogen production and storage technologies between 2002 and 2007 and RM34 million (US9.7 million) on the national fuel cell research and development from 1996 to 2007 as applications of fuel cells are viewed as one of the more important energy conversion devices in the future. Therefore, a task force under the PTM has been set up recently and the hydrogen energy roadmap for the next 20 years was drawn as shown in Fig. 3.

4.5. Nuclear

As the world struggles to cap CO_2 emissions and GHG and deal with climate change, nuclear energy is becoming more and more appealing. Fanned by climate change and dwindling fossil fuel supplies, there is now a nuclear renaissance. More and more countries are beginning to consider having nuclear reactors. In this region, Thailand, Vietnam, Indonesia and Malaysia have recently announced their nuclear plans. Nuclear energy has existed for

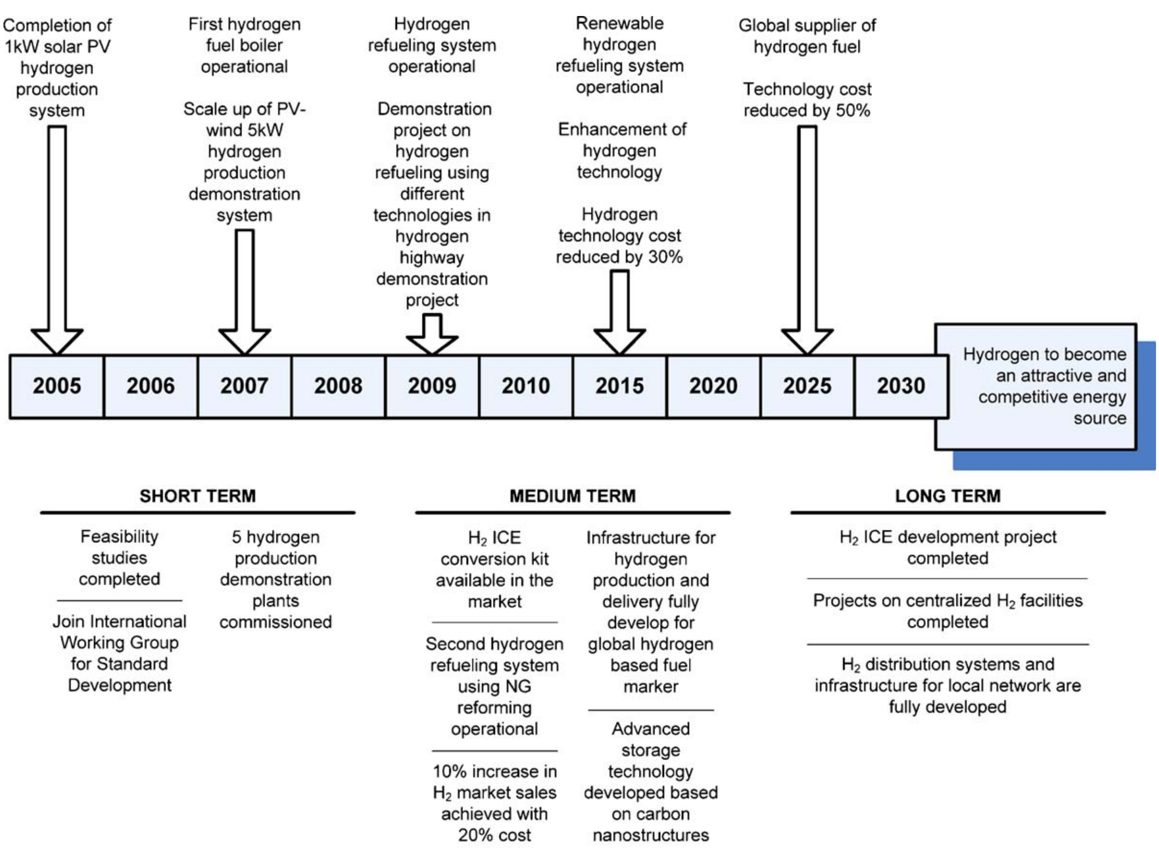

Fig. 3. Hydrogen energy roadmap for Malaysia [25].

many decades and is a popular energy source in developed countries. For instance, according to *World Nuclear Association*, 75% of France electricity needs are supplied by its 59 nuclear reactors and South Korea has over 20 nuclear power plants which supply 40% of its needs. Nuclear has long been considered as the only form of energy that can replace fossil fuels adequately, which currently provides 85% of the world's energy today. The burning of fossil fuels spews about 30 billion tons of CO_2 into the atmosphere every year but in contrast, nuclear reactors produce almost zero CO_2, according to *Environmentalist of Nuclear Energy*.

In Malaysia, control over the use of radioactive substances began in 1968 when the government passed the Radioactive Substances Act 1968. Due to rapid development of atomic energy activities in Malaysia which requires more effective control, inspection and enforcement, the Atomic Energy Licensing Board (AELB) was established in February 1985 to act as an enforcement body and was placed under the Ministry of Science, Technology and Innovation (MOSTI) since October 1990. Non-power applications of nuclear technology have contributed to improving healthcare, generating new industrial products and processes, improving food and water security, and further development of other areas of science and technology all this while. Such non-power applications have been the main focus of nuclear technology development in Malaysia until now.

As in many developed countries in the world, there is now a renewed interest in using nuclear energy for electricity generation in Malaysia. Recently in July 2009, the government has agreed to include nuclear as an option in the energy policy of the country, with the drafting of a new national energy policy expected to be readied by the end of the year. This is due to the realization that the available national energy resources are inadequate to guarantee supply beyond the year 2030 and in will take 10–15 years to develop the human capital to tap into nuclear energy. Currently, electricity generation in the country is predominantly based on only three of the five fuel sources, namely, natural gas, coal and hydropower. Oil is hardly used for electricity generation, except for standby generation, and the contribution of RE to electricity generation is still insignificant and far below the target set under the 9th Malaysia Plan (2006–2010). In future, oil will no longer be a viable option for electricity generation, due to the diminishing national oil resources, and Malaysia is expected to become a net oil importer by the year 2030. Furthermore, fluctuating global oil prices do not augur well for a reliance on oil for electricity generation. As such, the priority for the use of oil should be in those sectors where it is difficult to find a substitute, especially in the transportation sector. Of the three current main sources for electricity generation, there is uncertainty over gas supply to the power sector in the peninsular beyond 2030. To cover for the shortfall in gas supply, coal-fired electricity generation may need to be increased. This is not an attractive option, given that almost 100% of the national coal supply is dependent on imports, with current total of approximately 20 million tons per year.

With the increasing global demand for clean and sustainable energy, peaceful, safe and secure use of nuclear energy, further development of affordable and cost-effective small and medium-sized nuclear power plants (NPP) is important. For Malaysia, the nuclear power program can be initiated with a small nuclear power plant as a power demonstration reactor, before larger plants that are more cost-competitive can be built. This was the approach taken by Japan, which started with a Japan power demonstration reactor (JPDR) generating only 13 MW of electricity from 1963 to 1982, before building 53 larger plants with capacities between 340 MW and 1300 MW [26].

In view of the increasing global interest for nuclear power generation, especially among developing countries, there are concerns expressed by certain parties over the state of readiness of those countries adopting nuclear power. The main concerns have always been the nuclear waste disposal, followed by the need to decommission the NPP once it ceases operation. Both are expensive and thorny issues yet to be dealt with real effectiveness by nuclear-powered countries. If Malaysia were to pursue its nuclear future, there are few aspects that need serious consideration.

(1) Nuclear power is estimated to cost between US\$0.15–0.21/kWh whereas solar costs around US\$0.20. But the costs for nuclear are rising whereas for solar, it is dropping. Solar power does not present the problems of toxic waste containment, inflated capital costs and the political and security risks associated with nuclear power.
(2) Nuclear fuel is not as abundant as one might think. Uranium ore, which contains enough U-238 to make enrichment feasible, can only be found in a handful of countries. Some of these countries are politically unstable, others need the uranium for their own nuclear reactors, and some may use it as a mean of exchange (like Russia recently exchanges uranium with natural gas from Europe). Hence, the security of supply is not guaranteed. Furthermore, usable uranium is a limited resource, just like fossil fuel, and studies even show that the peak of nuclear fuel can be expected during the coming decade, similar to the peak of oil. NPPs are designed to last around 60 years and the radioactive waste such as plutonium has a half-life of 24,400 years. The process of enriching uranium for it to be used as nuclear fuel is extremely energy intensive and produces lots of GHG. Thus, nuclear power is not as carbon neutral as many had claimed [27].
(3) Currently, Malaysia runs at 47% over-capacity to compensate for fluctuations in demand and interruptions in supply. Such large reserves are quite adequate for years to come, and this does not even include the 2400 MW Bakun dam which has yet to be commissioned. Restructuring the set up of the existing energy sector which favours IPPs at the expense of TNB seems to be a more feasible way forward.
(4) It is estimated to cost US\$4 billion for a 1000 MW nuclear power plant (NPP), excluding other costs in running it, such as the waste disposal and other costs associated with the safety and security of the plant. Furthermore, the planning and building of an NPP normally takes 15–20 years and tends to incur cost overruns and construction complications. If the same amount of monies is pumped into solar plants which require minimal maintenance, energy can be generated almost instantly. Studies conducted by the PTM estimated that 6500 MW power can be generated by using only 40% of country's house roof tops (2.5 million houses) and 5% of commercial buildings alone.

5. Energy efficiency

As a significant element of Malaysia government policy, energy efficiency (EE) is explicitly addressed in the 9th Malaysia Plan (2006–2010) besides promulgating the use of RE to ensure energy supply sustainability for continuous economic growth. EE programs focus on energy saving features in the industrial and commercial sectors as well as residential in the domestic sectors. The industrial sector is expected to implement measures for improvements in plant, equipment and processes as well as the end uses. Efficient Management of Electrical Energy Regulations are to be introduced, Uniform Building By-Laws to be amended to incorporate energy efficiency features, and specifications promulgated for accurate and informative electrical appliance labelling to be further enhanced. Promotion of the use of high efficiency motors includes initiatives to develop local expertise in the

manufacture of energy efficient equipment and machinery. Energy efficiency measures are to be intensified in the industrial, transport and commercial sectors, and in government buildings [7].

The industrial sector is the largest consumer of energy, rivalled only by the transportation sector. Over the 8th Malaysia Plan period (2001–2005), the energy consumption was projected to grow at an average of 7.8% annually and more than double over a 10-year period if no initiatives are implemented to improve the energy use efficiency performance of the economic sectors. The manufacturing sector is projected to consume 38.2% of the total commercial energy at the end of 2005, an increase from 37.1% in 2000 or at the end of the 7th Malaysia Plan, a growth rate of 8.5%. In keeping the plan targeting the Malaysian industrial energy consumers, the Malaysian Industrial Energy Efficiency Improvement Project (MIEEIP) was jointly initiated in late 2000 by the government, Global Environment Facility (GEF) and United Nation Development Program (UNDP), with the mandate to reduce the barriers to industrial energy efficiency and conservation, besides building institutional capacities in relevant organisations for sustainability. Energy audit activities carried out in eight energy intensive industrial sectors (wood, food, glass, cement, rubber, pulp and papers, iron and steel, ceramic) revealed potential energy savings amounting to 7.1 million gigajoules (GJ) per year with an estimated capital expenditure of RM100.4 million (US$6 million). At the same time, the Malaysian Energy Efficiency Plan (EEP) envisages a potential energy saving of over 1400 GWh over the equipment life-time, equivalent to RM238 million (US$61.6 million) for an investment of RM33 million (US$9 million) by the government in program expenses over the remaining period of 8th Malaysia Plan, and up to 2006. Among the achievements of MIEEIP as in January 2008 include the following [28]:

(1) The E-Benchmarking activities have successfully compiled a database of more than 1500 industries built up from data sourced from the Department of Statistics (DOS). MIEEIP has developed an Energy Efficiency and Conservation Guidelines for Electrical Equipment (EE&C Guidelines).
(2) A total of 54 industries have been audited under the project, in the following sub-sectors: cement (3), ceramic (6), iron & steel (4), food (10), glass (3), pulp & paper (6), rubber (9), wood (7), oleo-chemical (2), plastics (2) and textile (2). A 56-page document called "Industrial Energy Audit Guidelines – A Handbook for Energy Auditors" was published.
(3) An energy efficient motor rating and labelling program has been proposed to the Energy Commission. A "Boiler Best Practice" guidebook was developed.
(4) Various promotional materials that have been successfully developed and disseminated to stakeholders and beneficiaries, by means of the quarterly newsletter (MIEEIP News), articles in professional publications, newspaper articles and advertorials and by means of numerous workshops and seminars.
(5) Helped to establish the Malaysian Energy Professionals Association (MEPA), and association of energy experts, which is open to energy practitioners of various academic backgrounds.
(6) A Master Energy Services Agreement (MESA) was drawn up by the MIEEIP Team at PTM as a sample document to assist energy services companies (ESCOs) and industries in the implementation of energy efficiency activities.
(7) Ten EE technology demonstration projects in energy-intensive industries (pulp and paper, glass, food, steel, palm oil) have been supported as well as three local equipment manufacturers (motor rewinding, fans) by means of technical assistance (feasibility analysis) and investment support (through the Energy Efficiency Projects Lending Scheme, EEPLS).
(8) One demonstration project (Heveaboard Bhd. in Gemas) based on ESCO concept has been successfully implemented based on the MESA.

Table 6 summarizes the reductions in terms of energy consumptions, costs and CO_2 emissions achieved by MIEEIP in all the eight sectors from a total of 48 audited industrial companies up to 2007.

A more recent EE effort in Malaysia that worth to take note is the Green Building Index (GBI). GBI is launched earlier this year by the Malaysia Architect Association and the Association of Consulting Engineers Malaysia (ACEM) to assess the impact of a new building on its environment based on the six criteria of energy efficiency (EE) – indoor environment quality, sustainable site and management, materials and resources, water efficiency, and innovation. The index is soon becoming a standard for all buildings in Malaysia because it recognizes and rewards advances in EE through better technology and smart design. In line with the National Energy Policy objective to promote the efficient utilization of energy resources, the government has introduced tax incentives for companies that provide energy-saving consulting services as well as for companies that incur capital expenditure for EE and energy conservation. The government is also embarking on energy conservation in the building sector, in particular the government offices. All government agencies are currently working towards reducing energy consumption. As for new buildings, the low energy office (LEO) building of the Ministry of Energy, Green Technology and Water (MEGTW) has set the benchmark for more buildings to be built in the country with EE and RE features integrated in the building design [2]. The LEO building was targeted to achieve a building energy index (BEI) of 100 kWh/m^2 per year and energy savings of more than 50% compared to buildings without energy efficient design. Following the success of the LEO building is the green energy office (GEO) in

Table 6
Emission reduction impact of MIEEIP energy audits.

Sectors	Food	Wood	Ceramic	Cement	Glass	Rubber	Pulp & paper	Iron & steel	Total
Energy consumption ('000 GJ/year)	1,835	1,032	774	21,557	4,000	611	5,080	4,223	39,113
Energy costs (10^6 RM/year)	42.2	13.5	24.1	204.2	97.8	16.9	84.2	160.1	643.0
No cost	24	8	39	1	31	57	52	64	277
Low cost	111	132	75	7	14	21	69	57	486
High cost	238	221	42	337	59	84	691	149	1,821
Total savings ('000 GJ/year)	374	361	155	345	104	162	812	270	2,583
Total cost savings (10^6 RM/year)	8.5	5.2	6.0	33.8	2.5	4.3	19.8	5.3	85.3
CO_2 emission reductions (kt/year)	28.0	30.4	14.5	444.7	8.1	18.9	194.4	22.8	761.7
No. of audited factories	10	7	6	3	3	9	6	4	48
Factories registered	471	75	54	54	18	134	134	148	1,088

Fig. 4. Installed solar PV system at Malaysia Energy Centre (PTM) building – Green Energy Office (GEO).

2007 which currently houses the PTM. At the moment the GEO building has achieved BEI of around 65 kWh/m^2 per year (without PV generation). With PV energy generation, it can reach up to 35 kWh/m^2 per year. Fig. 4 shows part of the installed PV system at the GEO building. With more and more government buildings with EE and RE features to be built in the future, it is hoped that the private sector will be encouraged to follow suit and practice EE as a way of life.

6. Challenges and a way forward

The newly restructured Ministry of Energy, Green Technology and Water has drafted a comprehensive RE policy linked to the National Green Technology policy. The RE policy provides the rules and funds to make RE an important component of the country's energy mix, overcome technological barriers, address existing market failures, create a level playing field for these technologies and drive down costs. But while the role of public policy is clearly important, it is not enough. The government must take the lead and find ways to generate public will in supporting the sustainable energy agenda. So far, the arguments in favour of supporting RE have been overwhelmingly environmental.

Undoubtedly, nuclear energy is seen as a viable and proven energy source to sustain national socio-economic development beyond the year 2020. This is not only to ensure national energy security, but also to help reduce total national GHG emissions, especially under the new global regime which will replace the current commitment under the Kyoto Protocol of the united nations framework convention on climate change (UNFCCC), which is due to expire in 2012. Aspirations for nuclear energy aside, REs remain the safest and cleanest of all potential energy sources in the long term. Despite the growing scientific evidence in favour of switching to RE, however, the economic and political arguments are less straightforward and involve difficult choices. Although the government has tried to promote RE in the past, for example, through the Five-Fuel policy and by setting targets under the five-year development plans, much of these efforts were ad hoc, and did not achieve the desired results [29]. The government's SREP Program was introduced in 2001 with a target of 5% (600 MW) contribution from RE in the energy mix by 2005 and despite various fiscal incentives, only two plants of 12 MW total capacity have been commissioned. Obviously, the progress in bringing RE generation into the mainstream has been slow and financing is still an issue.

The notion is further pursued in the 9th Malaysia Plan (2006–2010) which has also set a target of 5% RE in the country's energy mix but as of last year, the vast majority of Malaysia's energy generation mix still came from conventional sources, comprising gas (65%), coal (28%), large-scale hydro (5%) and diesel (2%). For any green technology industry to succeed, the right support mechanisms must be in place to create the market. One of the key stumbling blocks is the prohibitive price of RE that gives households and businesses little incentive to adopt the technology. Furthermore, Malaysians have become used to cheap energy, with PETRONAS currently subsidizing approximately 60% of the natural gas sold to utilities. Every type of energy has benefited from assistance in its start-up phase, and RE should be no exception. There is still massive support for conventional energy sources in the forms of subsidies and export credits. If RE were to be competent economically, it is important that RE receives the same treatment as fossil fuels. Otherwise, such subsidies should be removed or made transparent in order to create a level playing field. This can be partly overcome through a mandatory feed-in tariff, which has shown positive results in some countries. Under the scheme, which might be part of the RE policy, electricity utilities must buy renewable electricity at above-market rates set by the government. The higher price helps overcome the cost disadvantages of RE sources. Recently, PTM has proposed that consumers who use electricity beyond a certain minimum point are required to contribute 2% of their bill towards a RE fund, which will then be used to equalize the price between non-renewable and renewable sources of energy. The scheme could change the mindset of consumers as it is based on the "polluter-pays" principle.

According to PTM, biomass and biogas, micro-hydro and solid waste will be prioritized as RE sources under the policy. Wind and geothermal sources will play a secondary role and as for solar energy, the potential is limitless. Since electricity from non-renewable sources such as gas and coal are heavily subsidized, solar energy is actually very competitive. This trend is very likely to continue, as not only end users became more and more demanding for such offers, but also professional real estate players, among them major Malaysian developers and house builders who are actively promoting these 'green' solutions. For instance, Monier Malaysia, a local company which specializes in energy efficient roofing solutions, has seen systematic growth of demand for its solar product, launched last year when oil prices peaked. Globally, the overall solar photovoltaic industry generated revenues of more than US$100 billion in 2008. Malaysia managed to tap approximately US$4 billion worth of investment over the past three years and created 11,000 jobs, and the market is far from saturated.

Although there are numerous setbacks at present, such as difficulty in securing EE project funding, unattractive tariffs and lack of incentive for utilities to promote demand side management, lack of awareness among key decision makers in industry, inadequate measures to ensure quality of services provided by energy service companies, fragmented EE program implementation, legal and regulatory frameworks, and relatively low energy prices due to subsidize, the research and development of viable, reliable and implementable RE solutions appropriate for Malaysia will be of paramount importance and thus, need to be stepped up. While the RE policy is a welcome move, it must be supported by a larger umbrella policy that addresses energy and resource efficiency, sustainable transport and waste management, if Malaysia is to make headway in building a low-carbon society.

7. Conclusions

An over-dependence on non-renewable fossil fuels in Malaysia energy sector has made the country extremely vulnerable to

volatile prices and interruptions to the fuel supply, especially since Malaysia is expected to become a net oil importer by 2030. Concerted efforts undertaken by the government so far are slowly gaining momentum with concerns about skyrocketing oil prices and higher feed-in tariff, and they have definitely increased the public awareness on the importance of the RE in the country's sustainable energy system as a whole, although being met by countless obstacles from numerous parties. While it is quite obvious that Malaysia are not ready to embrace RE totally and replace non-RE with RE in the near future, the government, non-government agencies and public should not be complacent. Instead, they will have to take more initiatives and work together to promote the use of RE so that it will become more prevalent in daily activities, thus moving towards a green society.

References

[1] Mansor SA. Keynote address: international energy security forum, Kuala Lumpur; November 2008.
[2] Mansor SA. Keynote address: Powergen Asia conference, Kuala Lumpur; October 2008.
[3] Leo-Moggie A. Keynote address: Bakun Hydro electric project seminar, Kuala Lumpur; 1996.
[4] Badawi AHA. Speech in Dewan Raktay: 9th Malaysia Plan (2006–2010). http://www.parlimen.gov.my/news/eng-ucapan_rmk9.pdf
[5] National Green Technology Policy. Ministry of Energy, Green Technology and Water. http://www.ktak.gov.my/template01.asp?contentid=253
[6] Najib M. Keynote address: 14th Annual Asia oil and gas conferecne, Kuala Lumpur; June 2009.
[7] Hasan AF. Energy efficiency and renewable energy in Malaysia. Energy Commission. http://www.teeam.com/st_paper_15july09.pdf
[8] Energy Information Administration. www.eia.doe.gov
[9] Malaysia Natural Gas. www.eia.doe.gov/emeu/cabs/Malaysia/NaturalGas.html
[10] Dow Jones. Energy sector issues. Malaysia power matters. TNB issues; May 2008.
[11] Press: Malaysia Today. Govt. support needed for Bakun to be commercially viable, says Tenaga; 13 November 2008. http://mt.m2day.org/2008/content/view/14834/84/
[12] Daud WRW. Hydrogen economy: perspective from Malaysia. International seminar on the hydrogen economy for sustainable development; 2006.
[13] Hitam S. Sustainable energy policy and strategies: a prerequisite for the concerted development and promotion of the renewable energy in Malaysia 1999. www.epu.jpm.my.
[14] Sopian K, Othman MY, Yatim B, Daud WRW. Future directions in Malaysian environment friendly renewable energy technologies research and development, Universiti Kebangsaan Malaysia, ISESCO technology vision; 2005. p. 1.
[15] Solar Energy. Energy Information Bureau. Malaysia Energy Centre. http://eib.ptm.org.my/index.php?page=article&item=100,136,143
[16] GEO-PTM. http://www.ptm.org.my/PTM_Building/intro.html
[17] Suria-1000. http://www.mbipv.net.my/suria.htm
[18] Sopian K, Othman MY, Wirsat A. The wind energy potential of Malaysia. J ?A3B2 show 146?Renewable Energy 1995;6:1005–16.
[19] Energy Information Bureau. http://eib.ptm.org.my/index.php?page=article&item=100,136,144.
[20] Fauziah SH, Simon C, Agamuthu P. Municipal solid waste management in Malaysia – possibility of improvement? Malaysian J Sci 2004;23:61–70.
[21] Press: UNITEN: Gearing towards research excellence. 5 February 2008. http://www.uniten.edu.my/newhome/content_list.asp?contentid=3345.
[22] Biogas on grid-connected biogas power generation using landfill gas. http://www.ptm.org.my/biogen/download.aspx?id=90.
[23] Kathirvale S, Sopian MK, Samsuddin AH. Energy potential from municipal solid waste in Malaysia. J Renewable Energy 2004;29:559–67.
[24] Ong TH. Impact of thermal treatment plants. Seminar: solid waste management – are we heading in the right direction? 2006. http://undp-swm.seri.com.my/images/dr%20ong%20-%20incinerator%2001.pdf.
[25] Daud WRW. The road ahead in R&D in renewable energy. www.symbiosisonline.com/aug08_rnd.htm.
[26] Yusof F. International nuclear conference, Kuala Lumpur; June 2009.
[27] Energy Watch Group. Uranium resources and nuclear energy. EWG-Series No. 1/2006.
[28] Akker JVD. Final evaluation: Malaysian Industrial Energy Efficiency Improvement Project (MIEEIP). ASCENDIS 2008. http://www.undp.org.my/uploads/mieeip%20final%20evaluation%20report%20jan%202008.pdf.
[29] Pusat Tenaga Malaysia – PTM (Malaysia Energy Centre). www.ptm.org.my